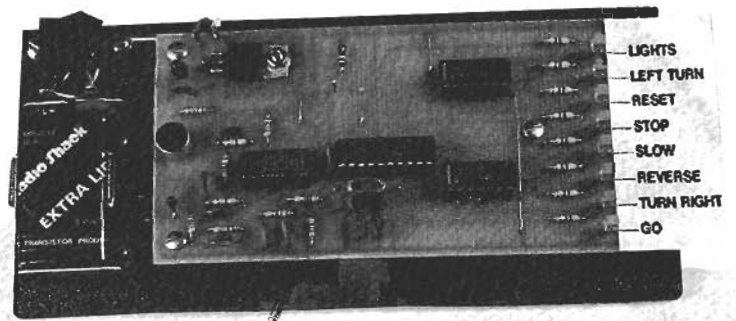


Here are two simple projects that will allow you to control things using up to eight voice commands.



EXPERIMENTS IN VOICE RECOGNITION



DANIEL B. COOPER

SOME OF THE MOST FASCINATING things that electronics experimenters can do are those that seem impossible. Remote control and voice synthesis are two areas of experimentation that were once nearly impossible for hobbyists and amateurs to work with, but integrated circuits have brought both within the reach of even novice tinkers. Another area that has always been very difficult to work with is voice recognition. And now there is a new IC which brings simple speech-recognition technology within the reach of novice experimenters.

Most voice-recognition projects and experiments have used personal computers as the backbone of the recognition device. A number of voice-recognition expansion cards for both Apple and IBM-compatible computers are available, but they're relatively costly and require the computer in order to be usable. The voice-recognition IC, the VCP200 speaker-independent word recognizer, is a stand-alone device that provides all of the essential elements for speech recognition in a single 20-pin package.

The project

There are a number of applications, both serious and fun, useful and merely entertaining,

for the VCP200. Rather than limit this interesting device to a single-purpose project, we are presenting two separate projects: one is suitable for experimentation—and also makes a nifty science-fair project—and the other is less ideal for experimentation but better for actual use in an application of one sort or another. A variety of adjustments and interfacing techniques will be discussed, and some flexible interface and driver circuits will be presented. None of the parts, with the exception of the VCP200 itself, are exotic or costly, and most are probably in your junk box or parts collection.

The experimenter's version is a self-contained device with a microphone and eight indicator LED's. The addition of a power supply is all that's needed. The project will recognize eight words and short phrases from almost any speaker, and light the corresponding LED in response. Outputs are provided for driving other circuits or devices.

The "working" version of the circuit eliminates the indicator LED's and their driver IC's, and uses a much smaller PC board. However, it retains the eight outputs and all other circuitry, and is therefore more suitable for building into a motorized model or other project.

Voice recognition

The basic elements of voice or speech recognition have been known for a number of years. Human speech consists of phonemes, which are the smallest individual units of sound that make up words and sentences. The "ah" sound in "father," the "t" sound in "top," and the "rr" sound in "radio" are all examples of phonemes. Any word in a particular language can be created by stringing together the proper sequence of phonemes and spaces of silence. Not all languages use the same phoneme sets; English, for example, lacks a glottal stop and the click found in many African languages.

Electronic voice recognition consists of analyzing the arrangement of phonemes in a spoken sequence and matching them against stored patterns or templates to determine the word or phrase. There are many variations in the actual processes used for each of the three steps: storing the patterns, analysis, and matching. However, the basic techniques used for voice recognition can be loosely grouped into four categories.

In speaker-dependent voice recognition, the intended user of the recognition device "trains" it by carefully pronouncing the list of recognized words, several

times each. The system creates detailed templates, or patterns of that speaker pronouncing those words, and stores them. The system will have a very high success rate in recognizing that speaker pronouncing those words, but it will be less able (if at all) to recognize another speaker saying the same words—and, of course, it will only recognize those specific words that it has been trained to recognize.

A discrete-word speech recognizer can only decode speech when it is a series of separately spoken words. It could not understand "Move the cursor to field one," but the sequence "Goto" (pause) "Field" (pause) "One" would be understood. Speaker-dependent discrete-word recognition systems are the most common types in use.

A speaker-dependent connected-word recognition device must be trained to recognize each different speaker's pronunciation. However, more powerful analysis capabilities allow decoding of words strung together in a long phrase or sentence. This type of recognizer could decode "Move the cursor to field one," but is typically costly and complex. The success rates are also typically lower than for speaker-dependent discrete-word recognition systems.

A much more difficult process is to decode the speech of a variety of speakers. No two people pronounce words in quite the same way. When analyzed electronically and graphically, variations, even with very similar-sounding speakers, are quite

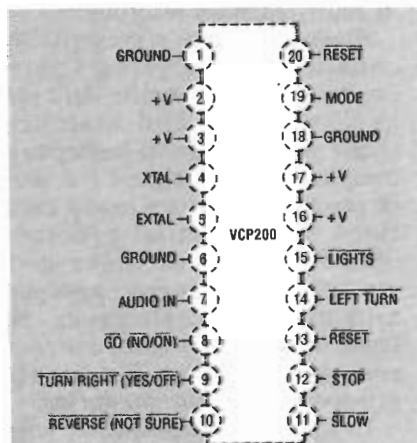


FIG. 1—THE PINOUT OF THE VCP200. The output pins 8, 9, and 10 respond to different words or phrases, depending on the operating mode selected.

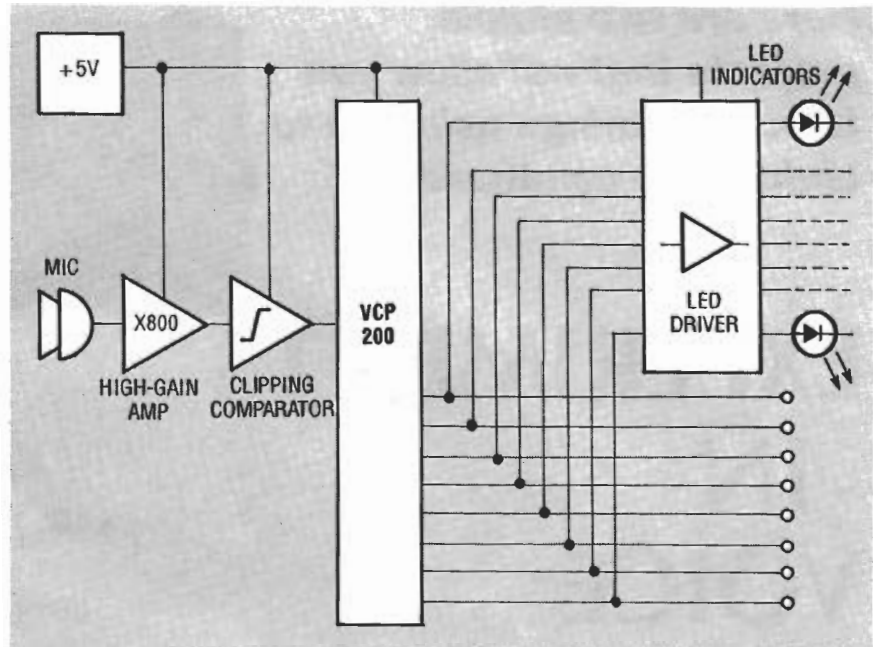


FIG. 2—BLOCK DIAGRAM of the voice-recognition circuit. The VCP200 contains almost all of the required circuitry, and needs only a power supply, microphone, and high-gain amplifier with clipping comparator output for operation. The LED indicators and their drivers are optional.

marked. That natural variation makes it very difficult for a system to recognize, with a high success rate, the same words spoken by different people.

Speaker-independent voice recognition follows the principle that all speakers have certain similarities in their pronunciation. For example, nearly all

speakers pronounce the word "stop" with the following similarities: an initial sibilant ('sss'), a short plosive ('t'), a soft vowel ('ah'), and a final plosive ('p'). By matching selected phonemes and allowing for variation in the matching algorithm, the same words can be identified and decoded from a variety of speakers.

PARTS LIST

All resistors are 1/4-watt, 5%

- R1—2200 ohms
- R2—1000 ohms
- R3—10,000 ohms
- R4, R7—470,000 ohms
- R5—11,000 ohms
- R6, R8—5600 ohms
- R9—4700 ohms
- R10—10 megohms
- R11—100,000 ohms
- R12-19—470 ohms

Capacitors

- C1—0.22 μ F, 16-volts, tantalum
- C2, C3, C12—0.01 μ F disc
- C3—39 pF disc
- C5—4.7 pF disc
- C6-C8—0.1 μ F disc
- C9, C10—27 pF disc
- C11—10 μ F, 16-volt tantalum

Semiconductors

- D1-D8—red light-emitting diode (optional, see text)
- IC1—LM324A quad op-amp
- IC2—LM7805T 5-volt, 1.5-amp voltage regulator

IC3—VCP200 speaker-independent word recognizer

IC4, IC5—CD4011B quad NAND gate (optional, see text)

Other components

JU1—switch or jumper (see text)

MIC1—electret microphone

XTAL1—10 MHz crystal

Miscellaneous: PC board (See

text), bus wire, SPST power switch, SPDT mode switch, normally open pushbutton reset switch, 9-volt battery or 8-15 volt DC power supply, 9-volt battery clip, three 14-pin IC sockets, one 20-pin IC socket, mounting screws and standoffs, 4-40 \times 3/8-inch screw and nut, hookup wire, solder, aluminum sheet for heatsink.

Note: The VCP200 may be available from Radio Shack (it has been discontinued but many stores still stock them) as part number 276-1308, or from VCPI, 1 Willings Place, Monterey, CA 93940, for \$14.95 postpaid.

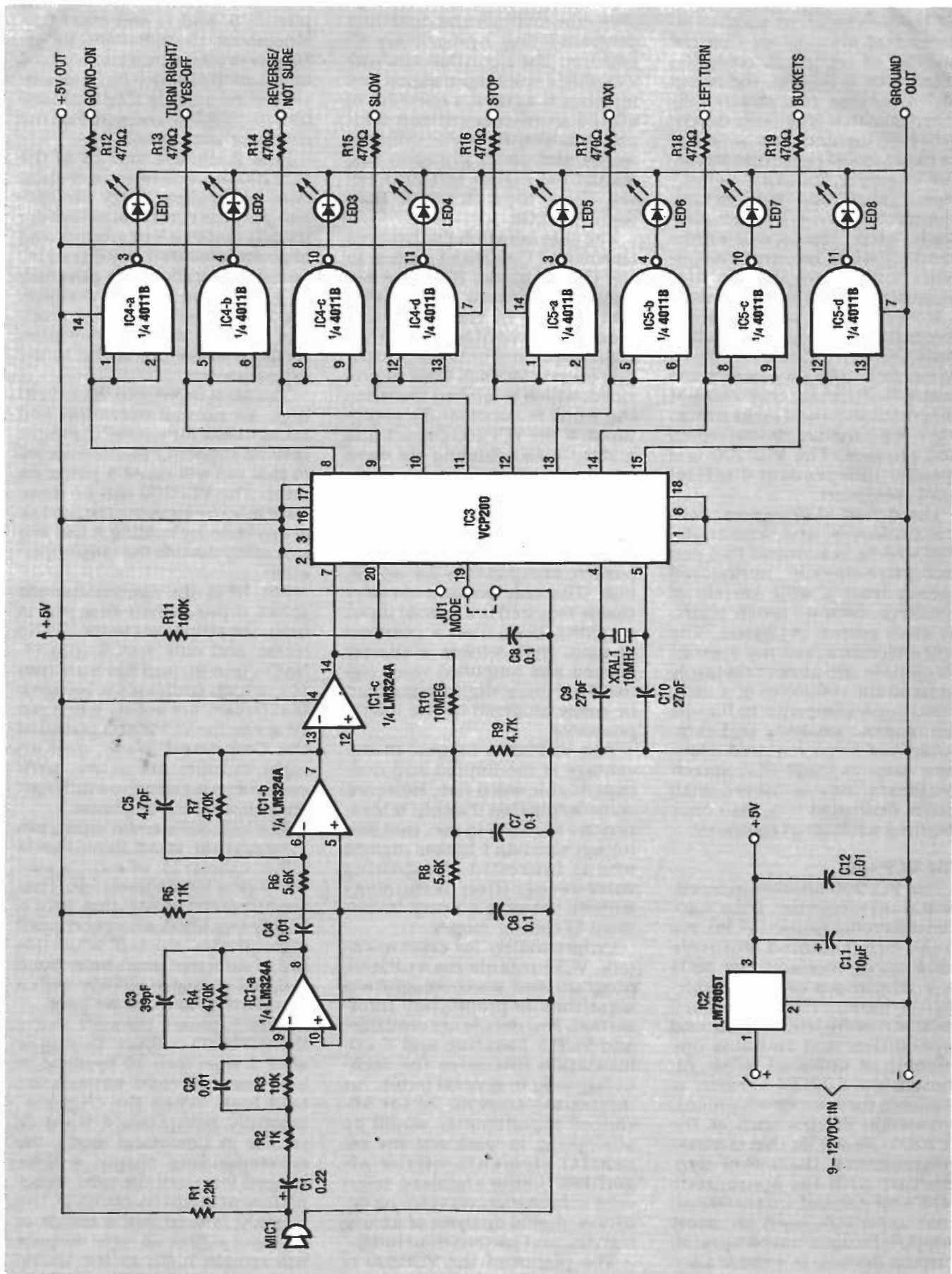


FIG. 3—COMPLETE SCHEMATIC of the voice-recognition circuit. The jumper JU1 may be replaced with an SPDT switch to control the operating mode. Either way will work, but the switch is easier to use.

The drawbacks to speaker-independent systems are that the number of separately recognizable words is limited, the recognition success rate is generally lower than that of speaker-dependent systems, and the system can be easily fooled by similar words. For example, "swap," "stat," "spat," "spot," and "spit" all have phoneme patterns that are similar to "stop." Most speaker-independent word recognition systems will be unable to distinguish between those words.

Most dedicated voice- or word-recognition systems are speaker-independent discrete-word types. Although they have some severe limitations, they excel at simple voice-control tasks involving a few carefully chosen words and phrases. The VCP200 is a speaker-independent discrete-word recognizer.

The dream of designers, control engineers, and science-fiction writers is a system that can recognize normal, connected speech from a wide variety of speakers. Despite much effort, no such system yet exists. The first successful "natural speech" recognizer will almost certainly demand the resources of a dedicated supercomputer to handle the massive analysis and computational steps required. However, keep in mind that speech synthesis, now achieved with single dedicated IC's, also once required a full-sized computer.

The VCP200

The VCP200 speaker-independent word recognizer, from Voice Control Products, Inc. (VCPI), is a mask-programmed Motorola 6804 microprocessor. The 6804 is a 20-pin device that implements most of the standard 6800-series instruction set and capabilities, and contains one kilobyte of onboard ROM. Although an EPROM version is available for user development, production devices such as the VCP200 use a ROM that is mask-programmed at the time of manufacture with the appropriate data and control information. That approach, used for many computationally-based special-purpose devices, is a viable alternative to designing a costly single-purpose chip from scratch.

The VCP200's ROM contains a

phoneme analysis and matching program using a proprietary algorithm. The algorithm analyzes a modified voice input signal and matches it against a selection of stored word-recognition templates to identify twelve different words and short phrases: Yes, No, On, Off, Lights, Left Turn, Reset, Stop, Slow Reverse, Turn Right, and Go.

The chip is switchable between On/Off and Command modes. In the On/Off mode, it recognizes only the two word pairs On/Off and Yes/No. In the Command mode, it recognizes the other eight words and phrases. A separate output for each word is provided, which is latched low when the word is successfully recognized. If the VCP200 cannot find a close match among its word templates, all eight outputs are left high.

The VCP200 is virtually a stand-alone device, requiring only a 10-MHz crystal and four passive components for operation. The only outside circuitry that is required is a special input amplifier, built from a common op-amp, that delivers a sharply clipped and amplified voice signal. That quasi-digital signal can be easily analyzed by the microprocessor.

The VCP200's biggest disadvantage is the limited and non-expandable word list. However, considering that the chip is inexpensive and easy to use, that limitation shouldn't bother anyone who is interested in exploring voice-recognition technology without making a heavy investment of time or money.

Unfortunately for experimenters, VCPI regards the VCP200's program and word-recognition algorithm as proprietary information. Few details are available, and VCPI's literature and documentation discusses the technology only in general terms. An interesting exercise for the advanced experimenter would be attempting to work out the essential elements of the algorithm, using standard reference information on voice recognition, digital analysis of analog signals, and pattern matching.

The pinout of the VCP200 is shown in Fig. 1. The chip is powered from a single-ended 5-volt supply, which connects to

pins 3, 6, and 1, and must provide about 15 milliamps. Its oscillator crystal connects to pins 4 and 5, each of which must also be tied to ground via 27-pF capacitors to complete and stabilize the oscillator tank circuit.

Pins 2, 16, 17, and 18 of the VCP200 are not used in a standard application. They are special-purpose control pins that are usually tied to +V or ground, and are connected that way on our PC board. Generally, these pins may be ignored, as they are normally used to set the VCP200 into various test and special-application modes that are not useful to the experimenter.

The reset input, pin 20, is held high for normal operation and brought low for a reset. A simple resistor-capacitor pair connected to this pin will cause a power-on reset. The VCP200 can be manually reset by strobing the pin low at any time, by holding it low, you can safely disable the chip's operation.

Pin 19 is the operation-mode select input. When this pin is high, the chip is set to the Yes/No mode, and only Yes/Off (pin 9), No/On (pin 8), and Not Sure (pin 10), which indicates a recognition failure, are active. When pin 19 is low, the VCP200 is placed in the Command mode, and all eight outputs are active, with each corresponding to a different recognized word or phrase.

The VCP200's audio input, pin 7, requires an input signal that is either quiescent, or swings past the digital logic thresholds. That requirement translates into a highly amplified, sharply clipped signal that is "shut off" when it is not of sufficient amplitude. Such a signal is easy to achieve with a standard op-amp, as we'll see.

Finally, pins 8 through 15 are the VCP200's outputs. During or after a reset (pin 20 brought or held low), all eight outputs are held high. When the chip successfully recognizes a word or phrase in Command mode, the corresponding output will be latched low until the next recognition attempt occurs. If the VCP200 fails to find a match to an input signal, all eight outputs will remain high. In the Yes/No mode, during or after a reset, pins 8, 9, and 10 (as well as the five unused outputs, pins 11-15)

will be high. Some recognition failures in the Yes/No mode can also cause all three active outputs to go high.

The circuit

As said earlier, there are two versions of the circuit. A block diagram of the experimenter's version is shown in Fig. 2. The circuit contains a power supply, an input amplifier and comparator, the VCP200, and output drivers. The power supply is quite conventional, using IC2, an LM7805T 5-volt regulator.

The input amplifier is not a conventional design; the output signal, if it were connected to a speaker, would be quite distorted and unlistenable. The purpose of the two-stage amplifier, with its overall gain of about 800, is to increase the microphone signal to a useful level. The output is then passed to a comparator that keeps the final output signal ei-

ther quiescent (flat-line) or switching between the supply limits—a quasi-digital signal. The output of the amplifier is passed to the VCP200's audio input, where the signal can then be analyzed.

The VCP200's eight outputs are made available, via current-limiting resistors, so that external interface circuits may be added to control motors, solenoids, and other active elements. Eight LED's are added to give a quick and easy indication of the circuit's response. The LED's are driven by CMOS buffers, which isolate the LED's from the outputs, preventing either the indicators or any outlying circuits from interfering with each other.

Figure 3 shows the complete schematic for the experimenter's version of the voice-recognition project. Note that the schematic of the working version would be exactly the same, except for the

omission of LED's 1-8 and IC4 and IC5.

Power for the voltage regulator, IC2, can be from 7.5 to 15 volts. Since the circuit draws only about 22 milliamps peak, a 9-volt battery is a good choice. Capacitors C10 and C11 filter and stabilize the regulator's output.

The signal from the electret microphone, MIC1, is coupled to the LM324A op-amp, IC1, through C1. The amplifier uses IC1-a and IC1-b to form a two-stage device that amplifies the microphone signals with a gain of 500-800. That transforms the weak input signal (under 5 mV) to a signal that swings from one output limit to the other, often with considerable clipping.

The amplifier has a restricted bandwidth, with a more or less flat response from about 500 Hz to 9 kHz. Signals under 300 Hz and over 15 kHz are sharply attenuated. That covers the

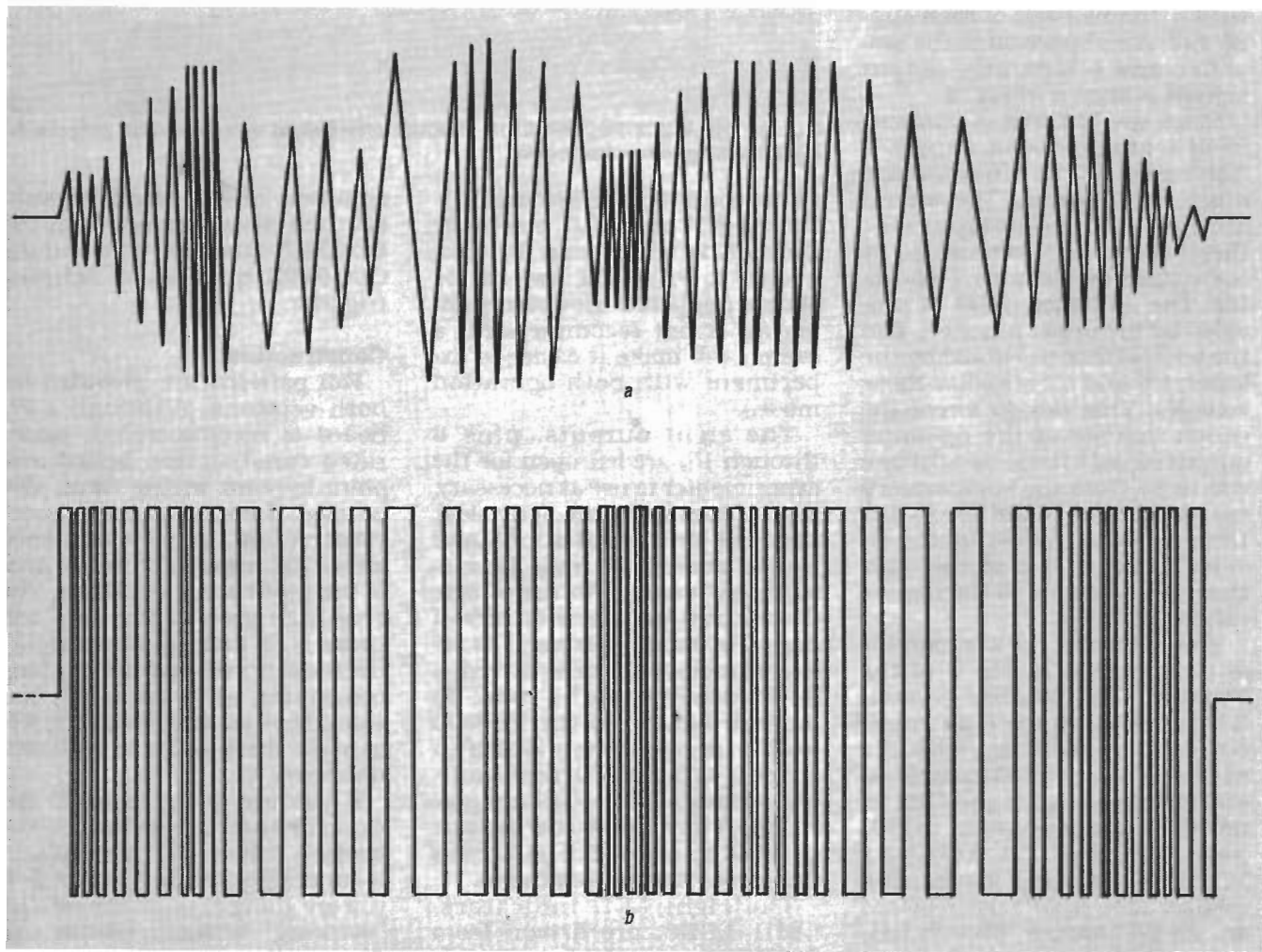


FIG. 4—AMPLIFIER (a) AND COMPARATOR (b) output waveforms. The comparator converts the amplifier signal into a clipped, quasi-digital 4-volt p-p signal only when the amplitude of the amplifier's signal exceeds the comparator threshold.

VCP200's input range of 300 to 5500 Hz, with some additional headroom for the easily-lost higher frequencies. The amplifier's characteristics are important, because the quality of the input signal largely determines how well the voice recognizer will work.

To keep the VCP200's input quiet, unless a signal of sufficient strength is present, and to ensure a sharply clipped signal, the output of the amplifier is passed to a comparator, IC1-c. (The fourth op-amp on the LM324A, IC1-d is not used, and its pins are left unconnected.) The comparator's output remains steady unless the input signal swings past its threshold. Input signals of less than 2.5 volts peak-to-peak will be ignored. However, all signals stronger than that will cause the comparator's output to swing from limit to limit, or about 4 volts peak-to-peak, which is within one-half volt of each supply rail. A comparison of the amplifier and comparator output signals is shown in Fig. 4.

Since the LM324A is operated from a single-ended supply, a "false ground" or offset voltage must be provided. The offset, along with the comparator threshold voltage, is provided by the voltage divider string R5-R8-R9. The amplifier offset is provided by the upper junction, and the comparator threshold by the lower; C6 and C7 stabilize those voltages. That design forces the center voltage of the op-amp's output signal to be separated by a volt or so from the comparator's threshold, and is the key to correct operation. Adjusting the divider string is one of the ways that the circuit's performance can be modified.

The output of the comparator is then routed to pin 7 of the VCP200. The 10-MHz crystal, XTAL1, provides the chip's master clock frequencies, with the oscillator tank circuit completed and stabilized by C9 and C10. To provide a power-on reset, the RC pair R11 and C8 hold the VCP200's reset input low for a few milliseconds after power comes on. As C8 charges through R11, the reset pin is brought high, resetting the VCP200.

The VCP200's mode input, pin

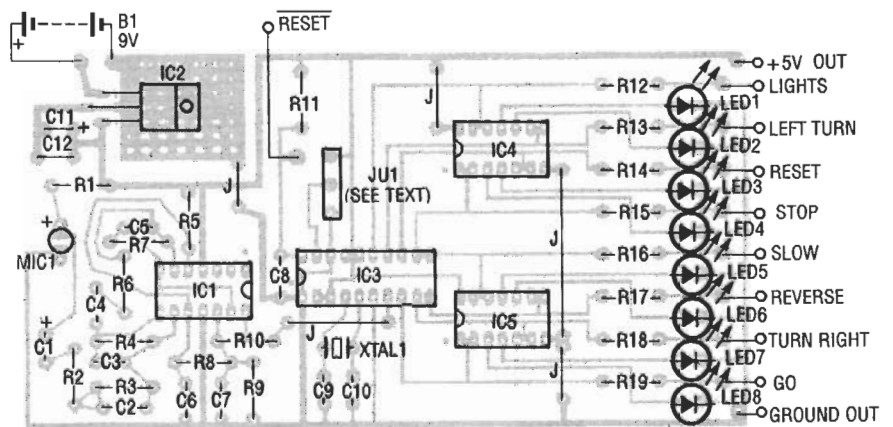


FIG. 5—THE COMPONENT LAYOUT for the experimenter's version. The "working" version parts layout is the same except for the smaller PC board that omits the LED's and their drivers IC4 and IC5.

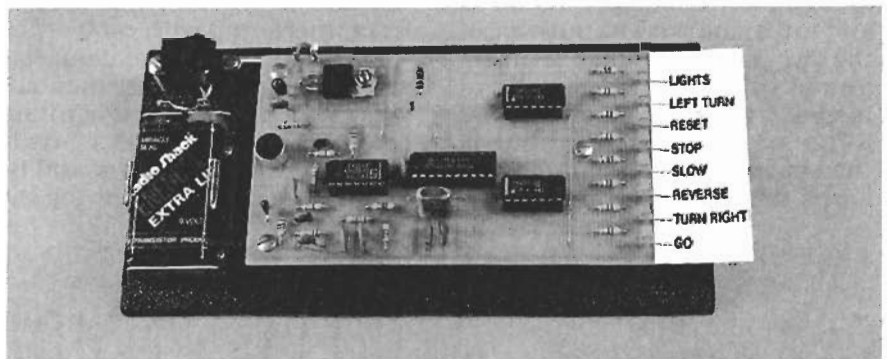


FIG. 6—THE VOICE-RECOGNITION CIRCUIT offers eight voice-activated outputs for experimenting with voice control.

19, is controlled by setting JU1. On the PC board, JU1 is actually three pads which may be connected to an SPDT switch, or simply jumpered. However, jumpering is not recommended; a switch will make it easier to experiment with both operation modes.

The eight outputs, pins 8 through 15, are left open for the experimenter to use as necessary. Since the outputs are active-low, they can sink about 10 mA and source somewhat less. That is sufficient enough to drive logic devices and transistor drivers. If high-current devices such as relays or motors are to be driven, a buffer/driver must be used. To prevent damage to the VCP200 from an accidental overload of an output, 470-ohm current-limiting resistors (R12-R19) are provided. They limit the output current to about 9.5 mA, even under worst-case conditions.

The eight LED indicators, LED1-LED8, are driven from CMOS drivers IC4 and IC5, which are CD4011B quad NAND gates. However, several other

common chips could be substituted here, among them the CD4001B quad NOR gate and the CD4093B quad NAND Schmitt trigger.

Construction

Foil patterns are provided for both versions. Although a PC board is recommended, perforated construction board and point-to-point wiring could also be used. If you use point-to-point construction, be sure and keep all wiring, especially in the area of the input amplifier, short. The very high gain of the amp will cause it to pick up and amplify electrical noise if excessively long connecting wires are used. You should use sockets for all the IC's to make them easier to replace if necessary.

If you are going to build the experimenter's version of the project, follow the parts-placement diagram shown in Fig. 5. If you are going to build the smaller "working" version, simply use the smaller foil pattern; parts placement is the same as the larger version, except that the

LED's and their drivers, IC4 and IC5, are left out. On both, keep the wire jumpers and resistors close to the board. Insert the disc capacitors so that their bodies are seated against the board, but don't chip the dielectric material. Be careful to observe the polarity on the two electrolytic capacitors, C1 and C11.

The voltage regulator, IC2, requires special mounting. The middle lead should be bent about 0.1 inch farther from the body than the two side leads, and all three bends should be made so that the regulator's mounting hole lines up with the hole in the board (see the photo in Fig. 6 for details.) If you are going to be using the project by itself, with no outlying devices powered from the board, no heatsink is needed for the regulator. If you are going to be powering other devices from the regulator that will increase the load to more than 100 milliamps, a heatsink should be added to the regulator. A flat aluminum stock heatsink can be bent into a shallow "U" shape and installed under the regulator. Because there is no space for a large heatsink, the current drawn from the regulator should be limited to no more than 250 mA even when using as large a heatsink as possible.

For most experimenters, mounting MIC1 directly to the board will be adequate. In some cases, though, it may be better to mount the microphone remotely. In that case, light-gauge shielded cable should be used to connect the microphone to the board. Electret microphones are polarized, so be sure the positive terminal is connected to the pad that leads to C1 and R1.

If you like, the eight LED indicators can be mounted remotely with a length of ribbon cable. If you mount them on the board, be sure to position them all at an even height. How you finish the remaining steps depends on how you want to use the board. For display and experimentation, you'll want the input and outputs of the circuit easily accessible with test points. Otherwise you can hardwire driver circuits and the like directly to the board.

In the prototype, the PC board and power switch are mounted to

| Command | Pronunciation | Comments |
|------------|---------------|--|
| Yes | yeSSS | Both of these words should be longer than "No" or "On," with emphasis on the final sibilant. |
| Off | awFFF | |
| No | no | These words should be kept very short. You'll find that almost any short, sharp sound will be interpreted as one of these words. |
| On | on | |
| Go | go | |
| Lights | LytSSS | Emphasize L and S. |
| Left Turn | LeFFFT Turn | Emphasize F and the two T's, and separate words clearly. |
| Reset | rESSSeTT | A difficult word for the VCP200 to recognize. Emphasize the first E, S, and final T. |
| Stop | SSSTawPP | Emphasize T and P. Keep short, but longer than "Go". |
| Slow | SSSlöh | Emphasize S and vowel. |
| Reverse | rEverSSS | Another difficult word for the VCP200. Emphasize first E and final sibilant, but do not separate syllables. |
| Turn Right | Turn-ryT | Emphasize T's and slur words together slightly. |

a thick plastic base using spacers and screws, and the battery clip is secured by smaller screws. Although the prototype has no reset switch and is strapped into the Command mode, you can easily add the controls. Just use a slightly larger mounting base and mount the switches in the same manner. If you are using the working version, and will be using it as a part of a complete project or more complex setup, use your judgment as to mounting the board.

Testing

When you have the board (either style) finished, leave the IC's out of their sockets and connect the power terminals to 9–15 volts DC. Then check for +5 volts DC at pin 3 of the regulator, pin 4 of IC1, pin 2 or 3 of IC3, and (with the experimenter's unit only) pin 14 of IC4 and IC5.

Disconnect power, insert IC1, and then connect power again. Check for an AC voltage at pin 7 of IC1. It should vary with the level of sound up to about 2 volts peak. Check the voltage at pin 14 of IC1. When the sound level is high enough, a 2-volt signal should be present. If the comparator is functioning correctly, pin 14 should switch between no signal and a 2-volt AC signal,

with nothing in between. If you're using an oscilloscope, look for a 0–4 volt signal at pin 7, and a 0 or 4 volt clipped signal at pin 14.

Once the board has passed these tests, remove the power and insert the rest of the IC's. When you reconnect power, all LED's should remain off, or if you're using a board without the indicators, all of the outputs should be high. Say "Go." The appropriate LED should light (or the output will go low). Try the other phrases to make other LED's light. Don't worry if the circuit doesn't seem to respond well—it takes a little practice to speak the words and phrases clearly enough for the VCP200 to understand. Table 1 explains how to pronounce the words so that the VCP200 will understand them.

Modifications

The gain of the amplifier may be adjusted by changing the value of R4, R7, or both. Adjusting R7 is preferred. The higher the resistor values, the higher the gain of the amplifier. Lowering the gain will lessen the circuit's sensitivity to background noise, but will require the operator to speak rather loudly and directly into the microphone. Raising the

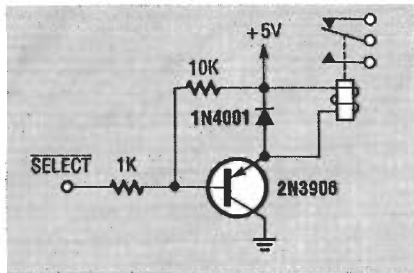


FIG. 7—BASIC POWER DRIVER CIRCUIT for interfacing the project to motors, lamps, or other high-current devices. The relay must have a 5-volt coil, but can have any arrangement of contacts suitable for the application.

gain will allow softer speaking from a greater distance, but at the expense of greater sensitivity to noise.

The frequency response of the amplifier is about 300 to 9000 Hz. Since the VCP200 responds to frequencies from 300 to 5500 Hz, reducing the upper cutoff point of the amplifier to 6000 or 7000 Hz would probably make it less sensitive to noise. If you are familiar with op-amp circuit design, a good way to improve the project would be with a high-precision bandpass amplifier. It should have a nearly flat response from 500 to 6000 Hz, with a sharp rolloff (third-order or better) at each end. The flatter the bandpass response and the sharper the cutoff points, the better the overall performance is likely to be. Higher frequencies are more sharply attenuated by distance and may need extra boost (actually less cut) in order for the VCP200 to successfully decode them.

The comparator threshold is set by the lower output of the resistor divider string R5-R8-R9. Since the artificial ground level or offset voltage of the amplifier is set by the upper output of the same string, some care is needed when adjusting either voltage so as not to disturb the other. The amplifier offset should be kept as close to +0.5 volts (or 2.5 volts) as possible, to ensure proper amplifier operation (i.e., balanced clipping of the signal). Thus, the series value of R8 and R9 should always be the same as that of R5.

If the comparator threshold is very close to the amplifier offset, very low-level sounds will be "digitized" by the comparator and make their way to the VCP200's input. That would permit better

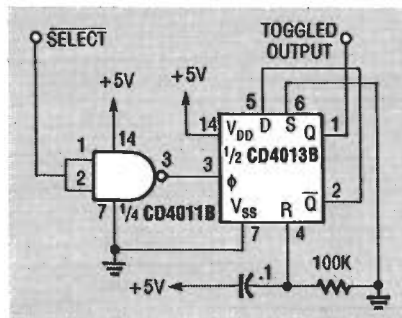


FIG. 8—TOGGLED, LATCHING interface circuit. The output switches states on successive occurrences of the associated voice command.

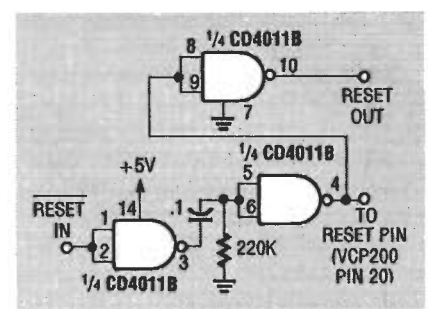
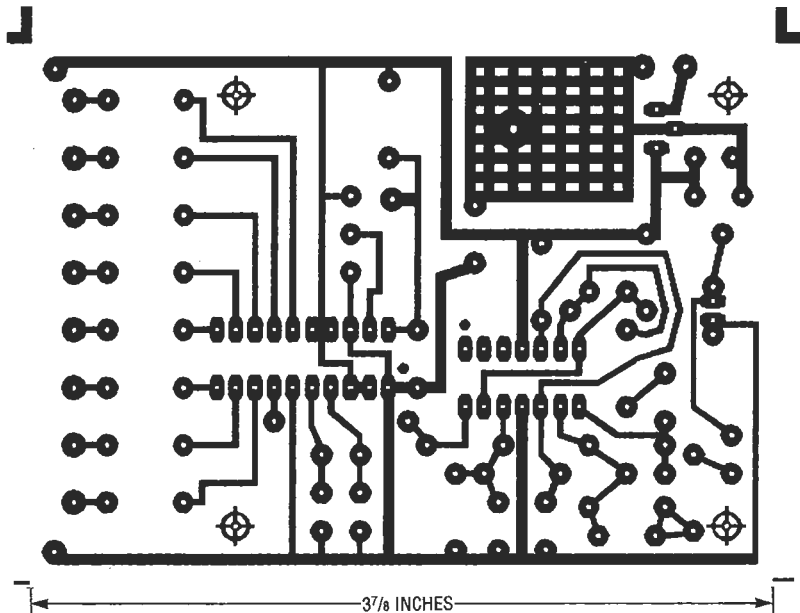


FIG. 9—THIS CONTROL CIRCUIT allows the project to be latched into forward or reverse motion while permitting other voice commands to be processed.



HERE'S THE FOIL PATTERN for the experimenter's version of the circuit, which includes the indicator LED's.

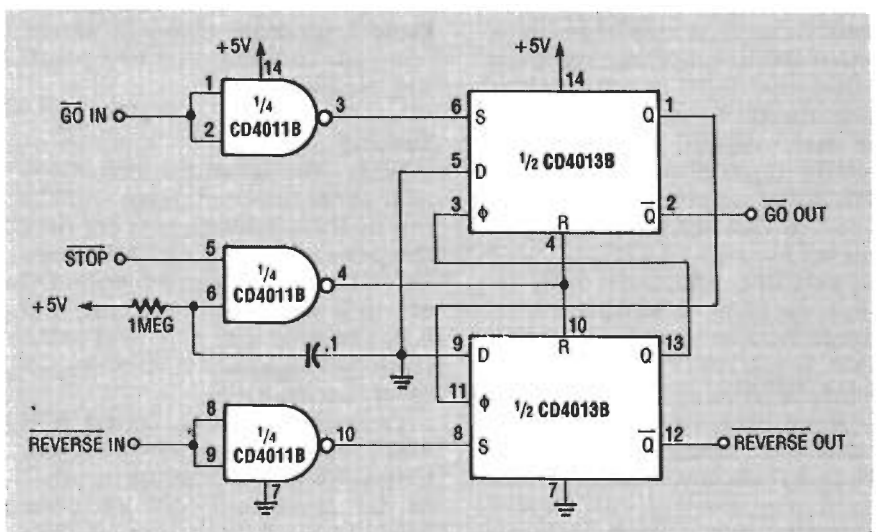


FIG. 10—A "SUICIDE" RESET CIRCUIT permits the voice-recognition circuit to be reset via voice command.

operation over distance or with softly-speaking users, but would make the unit prone to interference from noise. If the comparator threshold is set further

from the amplifier offset, noise will be rejected but louder speech or shorter-range operation will be required. For extensive experi-
continued on page 70

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VCP200

cont. from page 56

mentation, try using a 10K potentiometer in place of R8, and a 1K resistor in place of R9. 10K the tap of the potentiometer as the output to the comparator. That way, a steady amplifier offset is maintained while allowing considerable adjustment of the comparator threshold.

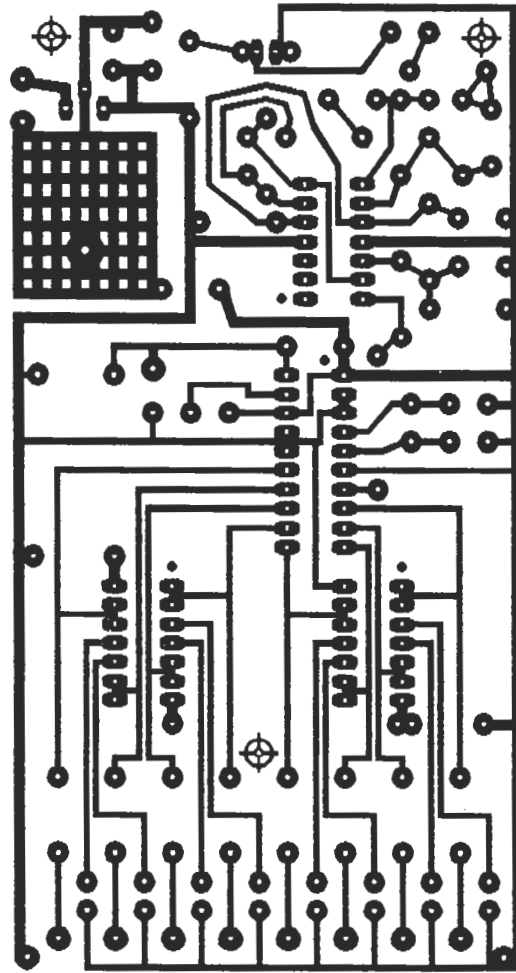
Interfacing

The outputs of the VCP200 can only source and sink small amounts of current and must be protected from reverse EMF and noise. Fortunately, a variety of interface circuits can be devised. One simple power driver is shown in Fig. 7. The desired output from VCP200 is connected to the SELECT input, where it drives the base of the PNP transistor. The transistor supplies power to the relay, which can have any type and arrangement of contacts necessary.

In some cases, it may be handy to be able to toggle an output device on and off. The circuit in Fig. 8 permits just that. Upon power-up, the output of the flip flop will be low. When an active low from the VCP200 is applied to the SELECT input, the output will latch high. The next active low will cause the flip flop output to drop low again.

A more sophisticated output circuit is shown in Fig. 9. On power-up, both outputs will be high. When the \overline{GO} output of the VCP200 is selected, that output will be latched low. If the VCP200's REVERSE output is selected, the \overline{GO} OUT output will be toggled high and REVERSE OUT will latch low. If a STOP signal from the VCP200 is received, both flip flop outputs will be toggled high.

The circuit in Fig. 10 allows a complete reset of the voice recognition circuit and any outlying



THE "WORKING" VERSION of the project is made on this board, which omits the LED's and their drivers.

circuitry with a voice command. When the RESET output of the VCP200 is selected, the monostable multivibrator, composed of the first two gates and the RC junction, produces a pulse that is routed back to the VCP200's reset pin, pin 20. That forces a reset of the voice-recognition circuit. The pulse can be tapped by another CMOS gate (either inverting, as shown, or noninverting, or both), and used to reset outlying circuitry. Given the imperfect nature of voice control, this circuit is recommended.

You now have some basic building blocks on which you can base your voice-control experiments. Keep in mind that, even though the command words understood by the VCP-200 are best suited for controlling a robot, they can be used to control virtually anything.

R-E